Project Introduction

On-Orbit Satellite Servicing brings the practical options of repair, refueling, and assembly to space-based exploration and commercial space ventures. It allows one to fix mistakes, upgrade quickly and extend operational life when needed. NASA's Robotic Refueling Mission (RRM) experiment aboard the International Space Station has demonstrated remotely controlled robots and specialized tools can perform precise satellite-servicing tasks in space using Canadian supplied laser 3D imagers. To our knowledge, Ball Aerospace and ASC Inc. are the only US suppliers of 3D laser imaging systems for autonomous rendezvous and docking. The OSIRIS-Rex asteroid sample recovery mission is dependent on ASC Inc. for the flash lidar navigation system. A second lidar system (from Canada) will be used for the asteroid surface topography science. We propose to develop a simpler, lower size, weight, power and cost, eye-safe, non-scanning system for future Goddard-led missions that may serve both the navigation and science purpose. Our main targeted application is robotic servicing for near-Earth satellites.

One of the technology pushes in the Human Exploration and Operations (HEO) line-of-business (LOB) is to develop low-latency telerobotics / robotic servicing technologies that allow for "multiple modes of control" by humans in proximity (when they are in orbit) and by human teams on Earth (like the Mars Exploration Rovers for robotic command of a complex, obstacle-ridden environment)... after humans leave orbit and allows for real-time situation awareness would help improve robot safety. High quality imaging sensors that have small size, weigh and power (SWaP), long to short range (km to meters) scanning capabilities with cm type resolution are necessary for proximity sensing or situation awareness and obstacle avoidance.   We propose to develop a non-scanning flash lidar 3D imaging system with goals of a low SWaP using TRL components that leveraging substantial in-house hardware. In this program, a laser with beam shaping optics generates a 32x32 pattern, which matches the sensor pixel layout on the Geiger-Mode Avalanche Photodetector (GM-APD) camera. This grid pattern is then used to illuminate the target.   A start pulse from the laser triggers the timer on the camera, as the reflected photons from the target reach the camera, the time of flight (TOF) information per pixel will be captured. This TOF information are used to form the topographic image of the target. The GM-APD camera is a 2nd generation camera from Spectrolab that has a much improved sensor, which factor of 16 reduction in dark count (now is 5 kHz). This upgrade will allow for a more sensitive detection sensor. Other important features for this 2nd generation camera are: Single Photon Sensitivity 32x32 Geiger-mode Focal Plane Array User-defined Range Gate User-defined Windowing (2x2, 4x4, etc.) Non-Uniform Bias (NUB) Correction for Improved Efficiency Camera Link Custom Processor Custom Image Processing Software Several of our key technologies enable this development (in contrast to the presently available systems): Use of a high-efficiency (> 50%) high power short pulse semiconductor monolithic master-oscillator-power-amplifier laser (vs. present

Non-Scanning 3D Imager for Autonomous Rendezvous and Docking

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< 10% solid state crystal lasers); Photon–counting detector based time-of-flight camera (vs. present poor sensitivity PIN arrays); Efficient optics that allow low-cost uniform array generation with laser spot-to-detector pixel one-to-one imaging vs. the present non-uniform illumination. We will design, build and test an integrated non-scanning eye-safe 3D imaging system. We will conduct laboratory and open-path 3D imaging experiments using our 1.5 km distance cell-phone-tower test range. We will work with the Goddard robotic servicing team and use their test facility to demonstrate real-time robotic operations

Anticipated Benefits

This IRAD demonstration can benefit areas in exploration in the near term by providing a non-scanning 3-D imaging sensor for missions such as remote servicing and sensor for situation awareness and obstacle avoidance.

Other potential area that this IRAD will have a direct impact is the scientific exploration of Mars via low-latency telepresence and Mars science landers application.

Primary U.S. Work Locations and Key Partners
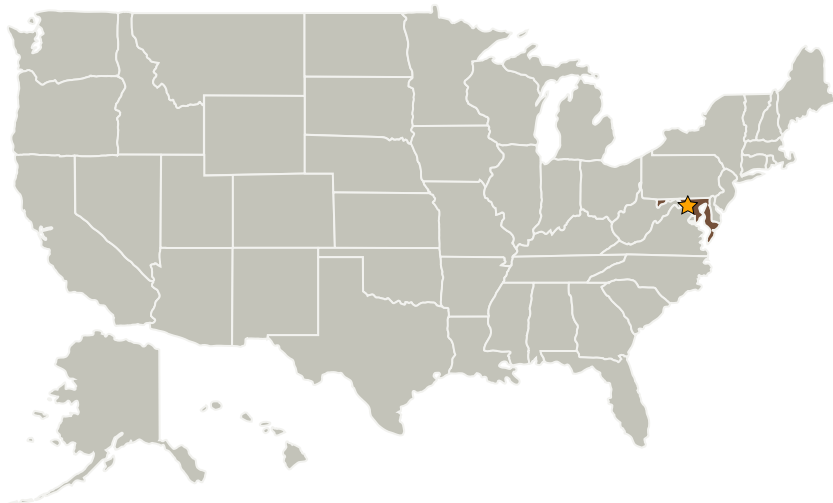
Organizations Performing Work	Role	Type	Location
⭐Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland

Organizational Responsibility

Responsible Mission Directorate:
Mission Support Directorate (MSD)

Lead Center / Facility:
Goddard Space Flight Center (GSFC)

Responsible Program:
Center Independent Research & Development: GSFC IRAD

Project Management
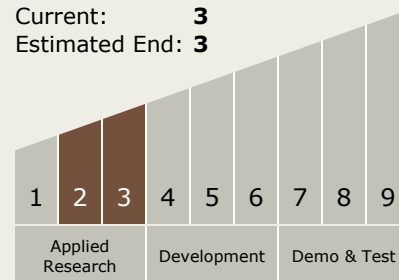
Program Manager:
Peter M Hughes

Project Manager:
Terence A Doiron

Co-Investigators:
Michael A Krainak
Nathaniel A Gill

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**

1	2	3	4	5	6	7	8	9
	Applied Research		Development			Demo & Test		

Co-Funding Partners	Type	Location
Boeing-Spectrolab Inc.	Industry	Sylmar, California

Primary U.S. Work Locations
Maryland

Project Website:

http://sciences.gsfc.nasa.gov/sed/

Technology Areas

Primary:

- TX04 Robotic Systems
  - └ TX04.5 Autonomous Rendezvous and Docking
    - └ TX04.5.1 Relative Navigation Sensors

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